Interview with A Rothenberg and Dr. Joshua Lederberg on May 17, 2002
at The Rockefeller University at 10AM.

JL discussed the existing tapes/transcripts with AR.

JL: What do you do with all this? I know you have had several books over the years.....

AR: The focus is on scientific creativity and such and my writings up to now have been more diffusely written about creativity so I have been focussed more on scientific creativity and I've worked with a number of scientists in Europe as a matter of fact so there is kind of a cross-cultural control here that I have been working on. Really one of the things I actually wanted to talk more with you about was that you sent me a lot of references on the issue of paradoxical thinking in science which as you know has been a main focus and your thought was that when we left, actually we were in the middle of it, that it is very common as an issue but I thought that you were reflecting on the fact that science presents paradoxes and there is an issue of sensitivity -- is that the way you think about it?

JL: All of the above.

AR: All of the above.

JL: I mean, we have an interaction between my mind and what's going on in nature and if I'm not looking for paradox I won't see it and if I don't follow up on it when it hits me on the head than I won't exploit it.

AR: Right.

JL: It's a cyclical process.

AR: Well, that's the precis...

JL: It's not very far from what you have been saying.

AR: I hope so. [laughter].

Many, many years ago when we first met, you made the point that symmetry was such an important matter in theory building in science.

JL: Symmetry, analogy, hymnology -- all those are related terms.

AR: Well, that's an important modification.

JL: Well, that's where my word association brings out. [laughter].

What does symmetry have to do with it? You have a template of how things are structured in

one setting and some things come along and you have to fit that template . That's the analogy.

AR: But there seems to be a focus on producing symmetry in theory building. All that fuss that was going on about _____ and such things as that , always the movement is to keep things symmetrical in theory rather than to go towards unitary phenomena.

Is that so?

JL: I'm a little puzzled about versus unitary. The formal definition of symmetry is that your object or the world looks the same when you move from point A to point B.

AR: Yes.

JL: So you see the same things. And you can generalize from geometry to broader, conceptual . But that's why it dovetails right into analogy. In fact we often use language in analogical fashion and there is a kind of symmetry there. We're using the same words which might exactly be the same phenomena.

STOP recording. Phone call.

JL: I think I've given you a piece I wrote for the Annual Reviews -- the introduction to the compilation of short memoirs in which I talked about some of the paradoxes of scientific thinking...

AR: I don't think so.

JL: Let me get you a copy.

Actually, _____ has a similar piece where he makes the same statement. I don't think I had read it before but it doesn't matter.

AR: Yes, I remember the _____ piece on scientific creativity. Do you mean that one?

JL: I don't remember the title of it.

AR: I think he gave it that title.

JL: Anyhow, the place I was fingering was where it is folded there, you see that little table, the box -- and if you had asked me in a few words to say where scientific creativity is lodged, it's one of the ability to parse through a very large number of logical alternatives and to generate them on the fly and then very quickly to also parse through their logical sustainability. In the meantime when things are unsettled to be able to entertain contradictory hypotheses without believing that you have to reject one or another for the time being-- maintain that dialectical ambiguity for a very long time because it very often happens that what seems to be contradictions aren't -- and that's what paradoxes are. That you just take

another way of looking at them and they become resolved and where people fail in their creativity is that they jump to conclusions too quickly or don't reach a conclusion because they haven't thought of it rather than sustaining that kind of inner dialogue over a long period.

AR: That's very much to the point. The question I have is when you say that you sustain the dialectic in your mind and whether in resolving it you think that you made a compromise between the contradictions, you superseded them, or whether you contain the element of the contradiction within the solution.

JL: The latter.

AR: That's a distinction from the _____ position and the latter is a critical one.

JL: I'll give you an example. You know some of the contradictions end up being truly verbal. You haven't thought through the semantics. So what's involved -- one of my important contributions was the introduction of the term and concept of the 'plasmid'. Before that time there used to be a heated controversy about whether a given particle was a virus or a gene. And the point is that it can be both. It's entirely a question if you are looking at it from the point of view of pathogenicity or looking at it from the point of view of heredity transmission. So, you know, genes can be pathogenetic and germs can be genes. There's not a real contradiction. So my ability to transcend that --

AR: And so was that a thought that you -- about being impulsive -- was that a formulation that came to you all at once or arrived at in stages . When you say parse it out --is the critical question here.

JL: It would be very difficult for me to say , these are things that happened fifty years ago,

AR: I know.

[laughter]

JL: I think they might have come later. I look closely at texts and I find that they are the germs of this idea in preceding years. If I only know how to look for them.

I think it had to do with how I dealt with them when I was first presented with these concepts. The first time someone introduced the contradiction or said there was a dichotomy, if I didn't say it aloud -- whoa, whoa, maybe both things can be true. Just that. That's a fairly common event.

AR: For you.

JL: For me. All of the above may be the right answer.

AR: For you. That's not the ordinary. In fact, on this particular issue , it's what you told Barbara Hyde. I'm trying to get that from the website. So far, I have not been able to do so.

It sounds like that with the genetic recombination you also did something of the same nature where you had contradictory ideas.

Is that not correct?

JL: There, I was contradicting a dogma. It wasn't the contradictory ideas were simply bacteria were asexual or bacteria are sexual.

AR: Yes.

JL: And that's not a dialetical opposition. It turns out that one is right and one is wrong.

AR: But it sounded like from what I hear.....

JL: Yes, it is a paradox

AR: You were about to tell her that it was an extraordinary thought that had occurred to you at a particular moment.

JL: No, the paradox is if I put it in these terms. Schistomiasis has a sexual phase. Schistomiasis is the technical term given to bacteria and it means 'fish and fungi' and it was meant to be taken seriously -- fishing and nothing else. So the paradox is that organisms that have been labelled or even defined as 'fishing only' are in fact 'not fishing only'. So the contradiction is at a verbal level. Not at a conceptual one.

AR: But opposition in itself is a verbal conceptualization. In that sense, our logic of opposition is based on verbal concepts. Is it not? Whether a man and woman are opposites as a grand parlance is not a logic thought.

JL: No. There is a true logical contradiction in the statements that bacteria do have a sexual phase and bacteria don't have a sexual phase. Only one of those can be true. And only one of them is true. The contradictions didn't have to do with the gut similar as a core issue. It had to do with the verbiage that it is surrounded and the world had accepted asexuality and institutionalized it in the term 'schistomiasis' and then stopped thinking about it. What the thought process being well if they're being defined as asexual what more is there to say.

AR: To conceptualize something such as that, I'm interested in the emotional aspect of this. Does that have a ..... I'm not talking about going back fifty years.... I'm just talking about it as a general question because I'm sure you still think that way. Is there a sense of anxiety about thinking about something new? Or is it only pleasurable?

JL: Well there is tension but I think it is called more of exhilaration than anxiety.

AR: Exhilaration when you know it is the right formulation but... on the course.....

JL: If I can get to a broader conception it helps me put order into the world one notch further. Ok?

AR: OK.

JL: That's exhilarating. Things fit that didn't seem to fit.

AR: But just for a moment -- back to the question of symmetry. Again, I was always interested in your making the connection between paradox and symmetry. So much of scientific advance does seem to have moved -- in all aspects of science -- on the basis of symmetry and in one way....

JL: That's the core of modern physics that cannot connect myself with much detail about that.

AR: Right.

JL: But a particle is a symmetry.

AR: And now there's super symmetries and all of that.

JL: That's a mathematical extension which most of us biologists and chemists don't actually ever use. But it comes out of mathematical formulas that are very, very powerful.

AR: Since I'm interested in creativity in art as well, symmetry is an issue but it is not a criterial issue of artistic excellence.

JL: There has been repeated commentary that ... I should give you my brother's website to act this up a little bit...he's a painter who has been pushing these very ideas that fractal symmetry has appeared very often in art but in music and to a very substantial extent in graphic arts, that perfect symmetry is boring.

AR: Absolutely. But scientists don't think that way necessarily. That's what I'm interested in. The scientists don't think that symmetry is boring.

JL: On the contrary. If you can find sufficient symmetry you can write down a few rules and derive the universe from a few first principles. That's not a direction I see art taking...

AR: No?

JL: But, I'm no specialist in it.

AR: But it is somehow pleasing to formulate something in a symmetrical way. You speak about something mathematically but there is an emotional content to it -- is it not in thinking scientifically?

JL: To the extent that you can find a way to make the world more predictable that you can embrace a larger and larger domains within the framework of a powerful theory --- that's a source of great satisfaction and that is what science tries to do.

AR: You don't think it is part of elegance then. You don't think it is a component of what is talked about as elegance in theory making.

JL: Oh, I think so.

AR: You think so.

JL: I mean that I'm not sure that I know what is elegant. That conforms to what I was saying a moment ago. I might not have the same estatic approach or the same estatic approach as others do.

AR: What I am trying to pinpoint is that....

JL: I want to go back to another point about my own biographical origins.

AR: Please.

JL: My father was an Orthodox rabbi and we had some tensions about quite fundamental religious issues but the one thing that we agreed upon was that monotheism in the Judaic tradition -- this is very Newtonian -- you probably are going to guess what I am going to say was founded on the notion that the world is governed by law. The human world and the natural world likewise. We have this extraordinary phenomenon of the blessing of having given us the Ten Commandments and the insight of the people blessing the constraints on their behavior... 'those shalt not'.... 'thou shalt not do this'.... 'thou shalt not do that'.... is such an extraordinary insight and such an necessary part. You know both of our political behavior and our social behavior which distinguishes us as human beings and a scientific outlook on the world. That the world is not run by demons who do exactly what they please and are totally unpredictable but is also governed by law. Now that is a theism that you can find in Spinoza and you can find in Newton. They probably would have been in stark agreement on many of those points. But I just wanted to mention the biographical component of this emphasis on order. But Einstein said many of the same things and that is not a coincidence that I am regurgitating them as I was very much influenced by Einstein as well.

AR: Were you religious as a child?

JL: My father was an orthodox rabbi.

AR: I know.

[laughter]

JL: I had no choice.

AR: And then -- the children -- there is a rebellion type element against such orthodoxy.

JL: Here again you can see the dialetical process going on. There were contradictions but there were resolutions of them and that on an emotional as well as a logical level -- that's

how my father and I were able to get along and we could respect each other's perspectives. His learning was in the Torah but he respected my learning in science. A figure like Einstein was a great help as a unifying paradigm. Here was someone Jews could be very proud of . He was not orthodox but nevertheless was looked up to by essentially everyone. To my knowledge no one ever criticized him for his lack of orthodoxy.

AR: I see that you have an engineer's diploma.

JL: That's a paradox. I have a hundred other diplomas but that is the one I put up there....

[laughter]

AR: It's very appropriate because Einstein's father was an engineer and I wonder with respect to your own father. You say he respected your interest in science. Was there anymore connection than that? Did he have some interest in science of his own?

JL: No.

AR: Was your mother?

JL: No.

AR: Was she a puzzle solver in any way?

JL: She was a very smart lady but had a primitive education and my father had been through a theological seminary and had very little secular education. He kept up with politics and everything but had no interest in science.

AR: But I'm focussing more on your creativity than on the scientific aspect. Was there some way in which he thought in ways that might have influenced you in some respect.

JL: Outside of the theological, the doctrinal questions we discussed -- no, I don't see it. Now that's a phenomenon I just don't understand. I was born with it. You have seen my seven year old essay, 'what I want to be a scientist'. I can't tell you. I've given you the traditions from which this arose but there were no role models. My teachers best benefits were to leave me alone. In fact, I have a little anecdote in that regard about my being a pest in the math class in either the sixth grade or something of that sort... and the teacher coming to me and saying that 'you know Joshua you don't have to prove to me that you know more math than I do. I know it's true. Why don't you collaborate with me in helping get our job done in terms of what's needed and if you want to study advanced calculus in the back room by yourself, that's fine. But don't contradict me in class, I have a job to do." She could deal with me as a grownup in terms like that. Bless her.

AR: Did you listen?

JL: Yes.

AR: And did you study calculus?

JL: Yes.

AR: When you talk about if you were born with it, I'm sure that your intellect -- there's no question about it but I'm interested in the other aspect of it which I don't know if you think it is separate but the creativities is not necessarily the same as the intellect. Many scientists have great intellects but they are not creative the same way as you are. Is that not correct?

JL: I don't know how to demonstrate my creative streak. I can demonstrate my precosity which meant that I was reading books five, six, eight years ahead of my grade but that doesn't prove anything else. I don't know how to verify that point. Being let alone is more the image than ... I didn't need inspiration. The library was my inspiration. The librarians helped me out. They let me take out an unconscionable number of books and I was able to get in the stacks of some of the big libraries and things of that sort. But I had no role models, no mentors. In that regard, in fact, I had very important mentorship but it's in the opposite direction. It's given me some discipline; teaching me to have some focus and not to jump from one idea to idea.

AR: Where was that?

JL: Francis Ryan, my young assistant professor at Columbia when I first went to college.

AR: So it wasn't until college, not in high school at all that you had mentorship.

JL: I had nurturing at the more personal level but these were from people who themselves would say that I have nothing to offer you. You are ahead of us but at least made me feel less lonely and gave me all kinds of affective encouragement.

What was I up to? Not enough discipline I say in a way that Ryan was able to do. He was much more advanced in his scientific education and so forth. At least he could keep up with me. My teachers in high school couldn't.

AR: I don't recall. Do you have siblings?

JL: Yes. I mentioned my brother, the artist. He's sixteen years younger. He was just here. He lives in Jerusalem and they had a gallery and, of course, went bankrupt over the last year or so. No business at all. He and his wife are both painters and so they came here and had some connections here and did famously in sort of a quick 'show and tell' tour in Washington, New York and Philadelphia and so on. I think they sold half of their inventory.

AR: Really?

JL: He appeals to a mystical streak. He's a calvalist. Quite thorough going and that shows through in some of his art. But he has taken a more modern approach in trying to portrary a more cosmological situations and that's rather an aggressive theme but he's come far enough along that it has a real appeal. I'm very proud of him now. It has taken years for him to

grow up. He's so confused between his religious calling and his art but has reached a kind of synthesis now for him.

AR: He's religious?

JL: Oh, very much. He's a follower of the Lubavitcher Rebbe and I think he is only just now very reluctantly given up the idea that he was the messiah. But I'm not totally sure he has given that up. To give you some idea -- he has a beard down to here.

AR: He must have been a child of your parents old age then.

JL: Yes. Sixteen years.

AR: Oh my. So you were alone all those years?

JL: No, I have another brother who is three and a half years younger. He has just retired as professor of biology at Brown. He has followed very, very closely tracking my.... Dov went the other way. You might say he is an X generation rebel against his big brothers.

AR: But there are two scientists then even though your father had no direct interest.

JL: Well, you usually think about Jewish doctors and lawyers but, as well scientists _____ social.

AR: Last time, Josh, you talked to me about....

JL: I need to know more about that though.

AR: Which?

JL: Whether to look for intellectual history or sociological interpretations of the role that is used in science. There is actually a piece I only just discovered by by Torstein _____ on this score which is rather extraordinary. It goes off the deep end in some ways and in different places but there are some interesting insights about that.

You have not heard about that?

AR: No.

JL: I have to dig that out for you and send it to you.

AR: What kind of position does he take on that?

JL: It's more geneticists that we would be comfortable with today but it also does talk about traditions of_____ facility of argument and things of that sort. And a little bit of the more sociological interpretation about being blocked from certain avenues of expression. I would have gone much further than he does in that regard. Now the children of the Diaspora

have to prove themselves and improve themselves in order to maintain themselves in the world. That's being marginalized to the extent the Jews had been as emigres. It has a lot to do with that flowery whipping now displayed by Asians for almost similar reasons. So that doesn't have much to do with intellectual history. That has to do with the social elements of it. But I still need to sort that out.

AR: It would seem like there would be some need for not marginality within the Jewish group to be a scientist particularly. Scholarship, yes. But looking for order to be a scientist....

JL: That may be difficult. But, you know, the attractions of Americanization which is what I faced. My parents had emigrated from Israel to the United States, another paradox.

AR: Were you alive then?

JL: No, that was before I was born. Approximately, a year before I was born.

AR: Why did they do that?

JL: Economics. Post World War I Palestine was disastrous.

AR: And they were long term Israelis.

JL: Both sides; especially my mother's side.

AR: Is that right.

JL: Well, it's not all Israel but it has been pretty well authenticated. You can go back ten generations to the _____ who is the _____ Tov's apostle. He is the teacher who brought the teachings of Hassidism. Ukraine, Central Europe and then went to _____ which is the center of Hassidism in Israel, proably around the middle of the 18th Century. My father is a little later than that. They came in the middle of the 19th century.

AR: And that wasn't for refuge in those days.

JL: No, no. It was religious.

AR: Did you speak Yiddish or Hebrew?

JL: Passingly, I wasn't too interested in it. I think my parents were just as happy to have a code of their own that they could speak in confidence in front of the children. They spoke Hebrew which was much unusual for Jews in the U.S. as well as Yiddish.

AR: Do you speak Hebrew?

JL: Not anymore. I had to learn it from my Bar Mitzvah. When I was eight years old my mother took the boys, my brother Seymour and myself, back to visit her family and parked us

for two or three months in a camp and that was sink or swim in terms of the language, so I picked up a fair bit at that point.

AR: A camp in Israel.

JL: Yes.

AR: What kind of camp was it?

JL: A boy's camp.

AR: Just a boy's camp.

JL: Not a kibbutz.

AR: What I was going to ask you last time and I think that this is the part that is missing from the transcript from our last talk was that you were telling me, very movingly, I thought about your assistant who died . What an important impact that had on you. I remember you said it affected you....

JL: You mean, in the automobile accident? Yes, Bob Wright. Well that has receded in time but I was just asking myself what might have happened to his widow and who had contact with her then. That was a long time ago and it was about the same time my father died.

AR: Was it so?

JL: Yes. Excuse me , not die, he had his stroke and was so totally incapacitated that he was not much more then a vegetable for 14 years. It's a slip of the tongue but not really die.

AR: You said it was more important than your divorce -- the effect on you of that event.

JL: Did I say that?

AR: Yes you did.

JL: I'm surprised that it went that far. So was that in '74.

AR: Well, that was this last time I think. I can guess you again about it and you can all take it back if that was not true. It was just .....

JL: You think it is in 2000?

AR: It was in that discussion but I'm sure it's not transcribed. What your secretary told me, it was the second half that didn't come through. But if you prefer not to talk about it.

JL: It doesn't sound right to me now. I certainly was bereaved by Bob's accident and he didn't die right away either.

AR: Also paralyzed?

JL: Yes. He eventually suicided and he and the family went back to Australia and put up a real struggle to try to sustain himself in academic life but he just couldn't.

As you well know the divorce is a blessing. It's the things that lead to it that are traumatic and totally reconstructured my personal life. That's long behind. I wouldn't make the assessment that you quoted. I am much startled by it.

AR: Well, because it was striking to me in the other direction. That's why I was asking again.

JL: Accidents are an acute traumatic event; totally surprising, unexpected , cut short a very promising career of a wonderful fine person. But it was somebody else. Your own family -- that's something else. That's an ongoing thing. The situation that led to divorce was a chronic problem for years and years. Finally, I'm at fault that I didn't take much more initiative to starting fresh at least five years earlier than I did.

AR: [inaudible] ....kind of clings to.....

JL: I didn't want to hurt her, my first wife. I wasn't doing her any good but I didn't construct it that way.

AR: Seldom does one do that. But she was very important to you. You did express that ....

JL: My student...

AR: Yes, that she had done a lot, worked very closely with her.

JL: I think I may have articulated in that I felt blest in that I had very few losses and I think you and others have made some comment about the role of early bereavements in personal development and I had everything go very smoothly for me. I sailed through school and no losses , a loving family. My mother may have nagged me now and then she would nag my father every now and then. So I don't want to paint it as idyllic but it was. In any real sense of the term I couldn't have been more fortunate . There were economic hardships but we got by.

AR: Do you think you were as productive during those years that were painful for you?

JL: You can measure productivity in a number of ways. My overt productivity was never greater than when I was in my early twenties and I did a string of work, not just at Columbia and Yale, '45 & '46, but through my time at Wisconsin-- another ten years. A half a dozen major discoveries rolled out. Now that had a lot to do with the state of the field that there were nuggets opening new territory. Nuggets to be found almost everywhere you went. You just remembered that when you stubbed your toe you picked up the rock to see what was under it and it was exactly that sense that what fell to us was one phenomenon after another. That got more difficult as the territory was explored and also when I started working in this

field there were perhaps as many as five people who were working in even remotely connected areas. Today there must be at least 25,000 and intermediate numbers at various stages so it became much more competitive to find things that other people were not working on. It was more difficult and so on and a little later on I found myself scooped one time after another. I would be pursuing a particular line of work in a fairly leisurely way and wanted to dot all the i's and cross all the t's and so on and that just didn't work in the scientific social environment. That was part of the story. And the other is that I became distracted by doing more things at a broader level. I mentioned being involved in biological warfare. Well everything you take on means less time for research and it is never more true today. I give barely ten percent of my time to my lab at this point.

AR: You referred to artificial intelligence some while ago and you told me the important.....

JL: Yes, that was a different tack and again I was more interested in starting a new field then in finishing up the details of an old one but I also saw a connection that with my experience in doing science I thought I could bring a perspective to how to have machine systems that would assist in doing science that others wouldn't have so I had excellent collaboration with the other specialties that would deal with the involvement with that field -- Ed Feigenbaum, Bruce Buchanan.

AR: You told me also, I do recall that you made a discovery there that was not subsequently recognized as your own. Isn't that true?

JL: No.

AR: you made an early recognition in artificial intelligence.

JL: Yes. But I did not lack recognition for it.

AR: I thought you said it had been absorbed....

JL: I've had plenty of recognition but over on top of that there's incorporation by obliteration.....no, what's that expression.... obliteration by incorporation. The approaches that we used have become assimilated into -- everybody does everything. Here's someone on our faculty who just came by my office a couple of days ago and he said 'I was so interested to see that you are here. A lot of the work I did for my thesis is closely related to what you did on the Dendral project twenty years before.

AR: Oh my....

JL: He was aware of it, so it's both acknowledged to people who have the self consciousness to want to know what the roots are but it is also totally incorporated. But I wasn't speaking with any lament. I have been very adequately recognized.

AR: Any you have stopped doing artificial intelligence?

JL: Yes. I don't have the milieu to follow up on it. It's beginning to be developed again,

just in the last year or two. For essentially twenty years, there was no computer science here. It was quite different from Stanford.

AR: What do you think its future is.....a continued future?

JL: Well of course it does and people have palm tops in their vest pocket that have more computing power than the mainframe that we were working with twenty five years ago and there are all kinds of things to be done with that. I think a lot of AI research has been stalled. It needs some fresh start in a number of places and I have a few ideas on how that might happen. I have been talking with some folks down at Darpa and some of my erstwhile colleagues on this about whether we might get a workshop together. Let's get a reassessment of where this field is -- where we left off twenty five years ago and see what fresh starts might be feasible. So many useful and successful things have happened anyhow so some many deep rooted changes might be impossible.

AR: Do you feel that you can conceptualize breakthrough in that field similar to microbiology?

JL: Not quite the same originality. It's hard for me to point to any one idea that no one has thunk before. We put it together in a different way. It's more of an engineering than a scientific.

AR: In that area there was nothing of the simultaneous contradictions that we were talking about earlier.

JL: Not in the core computer science part but there was a little bit of math that went along with it and this had to do with abstract descriptions of organic molecules. I'm going to get something out because it won't be intelligent otherwise.

it has to do with how you think through solving a mass spectrum. A mass spectrum.... things that you get out of a machine that breaks molecules into fragments, puts them into a little accelerator and then measures the masses of those fragments. From the masses you can fare what the elemental composition would be. So if I have an organic molecule, let's say, C7 H10, N2, O2, I want to understand how each of those atoms relate to another in space and then the mass spectrometer would help to solve this problem be breaking the molecule in a number of different places. Then it's a little bit like putting together a jig saw puzzle -- with all of these pieces and how they fit together in a way that is consistent with the masses given and from which a structure can be inferred. So in order to make this feasible we had to have a formal description in mathematical terms of what chemical structures would be like. This is what the computer has to be manipulating as it brings the changes. So intrinsically this was fairly elementary mathematics. The only thing it hadn't been done before. I had to go back to mid 19th century to find the roots and _____ of its applications to a systematic topology of organic molecule. Now the idea of doing that, you might say, was a breakthrough -- just for the fact that it hadn't been done. So to figure out just how to go about it took an awful lot of doodling and this is the end result . It was possible to develop a system by which you could not only describe the organic molecule but do it in a canonical

way. That's there one and only one way of putting symbols together that describe a single molecule. Because of symmetries of all kinds there can be a lot of ambiguity. There can be many different descriptions. If I turn a molecule on its head it can get a different numbering of the atoms and yet you are describing the same molecule. So this is what I had to go through in working out the underlying topology of molecular structures. So this would go on for months and months and months in trying to figure out the ideal way of going about doing it and one thing came after another and this did take a fair amount of creativity. This is just the mathematical underpinnings but it was what was necessary in order to be able to provide structures that the computer could manipulate in ending up with descriptions of organic molecules -- the ultimate solutions. So there is a lot of combinatorial optimization which you may have heard other ....

[laughter]

AR: I believe so. But there is a whole area that I haven't asked you about and I wanted to. How much do you visualize when you conceptualize? Here you are dealing with geometric forms and so..

JL: Yes.

AR: Do you use mental imagery?

JL: I do but it is a little more abstract than that and because it relates to a particular problem. Not the geometry. It's the topology. It's what connected to what that counts. Where they sit in space is sort of secondary. So I have a kind of imagery that enables me to manipulate those topologies even when I end up drawing these diagrams and you might say yes at some point -- I'm looking for some one --- these ring structures and so forth -- it's something more abstract than that.

AR: You don't actually mentally visualize these structures then. They become structures when you put them on paper. You don't mentally manipulate images in your mind?

JL: Less than you might think.

AR: Less.

JL: Yes. I do have... I guess it has something to do by imaging-- in other spheres .... well let me put it to you this way. In pursuing this work it has been important for me to avoid geometry. Geometry can be misleading. If I turn this structure around and have this group down on the bottom, that's a different geometry but the identical molecule. Then just imagine turning this on its side and so forth. So geometry gets in the way. There are false dichotomies. You have different geometries all described in the same molecule. Its what you get as the end result. What's connected to the molecule is what is important to me. And I may get to a higher level of abstraction than the geometry. You know the settings if often I am thinking about what's going on in bacterial conjugation. I'll play the same game that Einstein did in writing a lightwave. I think of myself as being a bacterium and what and how I am going to sense other organisms and what is it that is going to be a signal to me to send

out _____ and what is going to be a signal to start unrolling DNA and sent it through and so forth. In there there is some imagery involved. But my problem with imagery is that I cannot do logic on images. I can't draw necessary implications from pictures and I need forms from which I can do syllogisms.

AR: You once told me that you visualized yourself as an enzyme.

JL: Yes, that's similar.

AR: Similar to what you were saying as being a bacterium.

JL: But that is transient. I work very hard to reduce that to a form of expression from which I can then do logic.

AR: Let's say it is not an ongoing experience, such as one image following another or superimposing upon another.

JL: Oh yes. It's there.

AR: It's there.

JL: But I'm probably less visual then a lot of other people are. More logistic.

AR: And again you talk about .....

JL: One of the ways in which I can generate all possible images. That's the Dendral paradigm. Having all possible structures then you winnow them out with what the data have to say and what substructures are ruled out and don't even think about in trying to put together other structures and so on. Eventually you end up with something manageable. All possible structures is like library. Do you know that wonderful story . I'm just going to leave you to look it up. Believe me you need it.

[laughter]

It's a short story and it's in any number of his collection of works.

You'll enjoy it when you see it.

AR: Oh. You said the images do in sequence. Is there anything similar to what we talked about in logic. You take images and put them in the same place which would be a contradictory kind of spatial phenomenon in your mind. That doesn't happen.

You don't have images that are incongruous is what I'm trying to say in your mind.

JL: That's not the level to which I explore.

AR: Contradictions.

JL: No, I'm much more verbal. And logistic than that.

AR: Right.

Back to the symmetry question. You mentioned....

JL: A lot of my work had to do with providing notation that would translate from that to linear strings like this.

These are all expressions of structures of organic molecules. By making linear strings out of them, I can sort them, I I can find out alphabetical order, I can find canonical forms, I can put two together and see whether there are possible ways that they can interact with one another and so forth. Getting away from it is very hard to do.

AR: Now that's important distinction.

JL: Now I've wondered if there is a little piece of theological history involved in that and it has to do with the prohibition against graven images.

AR: Oh my.... [laughter]

JL: It has to do with what my environment would have been like. It's not that I read that commandment and took it literally and so forth but that tradition governs the whole historical tradition in which you and I are both imbedded and the focus on the text .

AR: Here you have a brother who is so visual...

JL: I know. He was doing it very crudely to start with.

AR: So you think he had to struggle against ....

JL: To begin with, all of his productions were _____ embellishments of the _____.

AR: Oh my. [laughter]

JL: He would do puns on scripture. You know _____ instead of in the beginnings _____, blessed be the seventh.

[laughter] combined talking

JL: I just had to prove my point. I quite never connected my brother's evolution is what I am saying.

AR: On the topic of symmetry again. You say you use symmetry here. I don't think I can ask another scientist this question but you because you are so sensitive to the issue of interaction between the mind and phenomena. You said earlier that it is both your

recognition of the contradiction and use of the contradiction.

[pause]

JL: Let me get back to the point though. Did you ever get Horace Judson's book when we were talking about the role of imagery and scientific creativity and so on.

AR: Who? Judson.

JL: Horace Judson.

AR: No.

JL: I think I cited it.....

He's an historian. He wrote the "Eighth Day of Creation" which is THE book on the discovery of the structure of DNA.

What I gave you before from the Annual Reviews, I think I refer to Judson in that.

But I don't see where that reprint went.

AR: I have it.

JL: Ok. No. 7.

AR: Was there something more you wanted to say about that?

I'm wondering if the issue of symmetry isn't structurally built into a human thought particularly; but certainly a scientific thought and I'm wondering if there isn't an interaction with the world that goes on for the scientist and if that because of both the mathematical and perhaps even aesthetic preference for symmetry -- that there is a tendency to make discoveries that have symmetrical structures to them which could mean that , in fact, it is the limitation of knowledge rather than it is only the facilitator.

JL: Well, symmetry is a wonderful assist for cognitive processes. Come stand next to me -- a small experiment -- now look at that wall.

[laughter]

AR: There you go. It couldn't be better could it?

JL: Now symmetry gives me a way of organizing knowledge. I can locate things...

AR: Exactly

JL: I can find out where things are missing....

AR: But, mathematically as well.

JL: Yes.

AR: It's a conservation to use a symmetrical formulation. But it is also emotional. We grow up.... there's a reason we are attracted to symmetry.... it also has to do with trees, and gravity and our bodies.... are symmetrical and all of those things. So I am saying that human beings are, and I am asking your opinion about this, are attracted to symmetries. That has been a limitation of knowledge because if you look at art , which we were talking about earlier, artists really find new symmetry or anti-symmetry more appealing...

JL: They have to do something new and different and the world of symmetries have been so totally explored .

AR: But you do new and different with symmetry?

JL: Yes.

AR: So, it's like saying....doing something unusual is creative but it isn't. There has to be some real structure to it. My question is -- would it be beneficial for scientists to think more outside of symmetrical structures. I mean in physics with symmetry breaking and things such as that which has become like a move ahead.... isn't it?

JL: You can only get there without being thoroughly imbued with what the symmetries are in the first place.

AR: Right. Asymmetrical and _____ to be sure.

How about anti-symmetry. How about that?

JL: You are still thinking about symmetries.

I'm resisting what you are saying because the whole process of scientific knowledge is the development of theories with predicted behavior that look for the symmetries in the world so that you don't have to deal with each situation _____. So it is possible to abstract , generalize. If I want to find everything in this room that has to do with genetics , I can point to that one shelf and it's all there. Otherwise I face the job of picking up every stone, one at a time and seeing what's under it. We're far from exhausting what symmetry has to offer us. I don't think we are ready to go into chaos.

Chaos theory is the reduction of chaos.

AR: Oh yes. I think chaos theory is very symmetrical.

But when we were talking earlier you said that when you deal with contradictions, that one of the ways that you cope with that is to find something beyond that. That's breaking the symmetry -- isn't it?

JL: I would say quite the contrary. There are common elements to viruses and genes that enable you to unify them under a single heading. I can point to one place on the shelf and show their relationships to one another and I can organize a great deal of knowledge by putting those two concepts together; but are seemingly at war with one another if you put them in different places.

AR: But doesn't unification in itself imply broken symmetry. Because it is now a unity -- is no longer a duality that can be symmetrical.

JL: I look at it almost the other way around. Now having understood if you are a gene or a virus --- has to do with the immediate context in which you are examining it. For every living particle that there is out in the world say this is what it is like to be a gene; this is what it is like to be a virus. Then I ask that same question over and over again. That is a symmetrical organization.

AR: OK. It goes back to what you were saying in some ways about the religious kind of question. Your brother is moving away from _____ issues in his art but He's the guy that does these massive, virtually mono- chromatic paintings. Minimalist field painter and he does things that are called zip lines. He did. One famous one is 'who is afraid of red, yellow and blue'. He became religious and thought he discovered in his art the opposite direction that he calls 'oneness'. Then he starts applying a lot of Judaic tradition to this idea of oneness -- the Exodus and all of that. Now when you said you came out of the Jewish tradition, monotheism is a non-symmetrical notion. Wouldn't you think that you would expect to go in that direction?

JL: I don't see it as so non-symmetrical. Quite the contrary. It's a kind of order into the world that didn't exist when you had your polytheistic, ... every natural phenomenon has its own natural god behind it.... behaving quite capriously. I turn it the other way around.

AR: I'm glad to elicit that from you. That's very important.

JL: Look what Moses did. He brought the Law down. It was reduced to Ten Commandments. All you needed to know in order to live a good life is ten lines.

AR: So, those are the issues of reduction, simplication. That's often referred to as eloquence. Would you say that?

JL: Yes.

AR: The order and the eloquence.

JL: Maybe we write them a little different today. Consider what an advance it was to have rules for good living codified in that way -- or just the idea of a code -- is even more of a point.

AR: Does that apply to your current work that you are doing? Bioterrorism -- are there other factors?

JL: No -- that's not a world of science.

AR: It's not.

JL: No. It's just a broad range of disparate data that have to be put together. I'm trying to think of what theoretical framework . There are some things I'm doing that I'll articulate what you just described.

I've decided that I'm such a gloomy view, let's put it this way of what lies ahead of us in the applications of bioterrorism that I don't think we have good technical solutions in the offing and that the offensive is going to be way ahead of the defensive for a long time to come. Everything more we learn on how to deal with infectious disease is another bullet for the guy that wants to shoot us with it and so I've tried to turn my thinking into a different direction. Just my ability to do that may be what is creative ... or anti-creative in this regard . But I'm able to do it largely because I'm no longer alone among microbiologists and others worried about these years -- pretty much a voice in the wilderness.

So I'm exploring what might be called the remediation or alleviation -- social or political. What can we do in order to make it less likely that people will practice biowarfare rather then concentrating on how do you build armor against it if they decide to use it. That's very tough. I don't have many good answers in that regard but just my raising that question -- I am going to put this to you as a psychologist. Twenty years ago we didn't think about smallpox for two reasons. 1) the world was still vaccinated against it although it was just at the end of the eradication campaign and 2) it was so uncontrollable that who in his right mind would use it because it would not be confined to targets. It would flash back. You know a successful attack on the U.S. is an attack on the world. If we don't contain the epidemic, it will spread globally.

So the question I'm putting -- let's not see this in the press -- is 'should we quietly undertake a campaign to make sure all the perps in the world understand this -- that they're playing with fire that will burn themselves if they use these kinds of agents'. Do we need to imbue that sense of vulnerability to the whole spectrum to our partners in the world -- our friends, people sitting in the middle, even people who are hostile to us but we have common ground in not allowing smallpox to be ever used and then we have possibly some small advantage that the political and law enforcement machinery and their overall planning, even in those countries will be more constructively oriented because there are some shared goals amongst intense adversaries.

I was talking to the Director of the Central Intelligence about this yesterday. He said "it's not my responsibility to make those kinds of policy decisions". I said, yes, but you have to help advise about what the implications would be of undertaking that kind of campaign or not. It provokes and inspires more people than it ends up deterring -- how rational our adversaries and so on.

JL: What's your own view on the matter -- pursuing a campaign of this sort -- talking about these hazards are people who are likely to do bio attacks of any kind deterrable by this kind of insight.

AR: Two thoughts about it. One is that it is structurally another example of your thinking -- turning the problem around on its head. You are thinking about it from the point of view of the perpetrator not the defender. So it's another example of the issue of looking at it as contradictions.

Personally I don't know the answer to -- if you are asking me for a personal opinion -- it is very hard for me to understand the psychological construct of these people. I was just reading a article in the Times today about Pakistan. Did you see it? It's about the women in Pakistan who are raped are considered to be adulterers and this woman was sentenced to be stoned to death. She was raped by the brother of her husband and that kind of conceptualization I don't think allows for means end thinking of the kind of thing you are suggesting. There's such a restriction on thought and basing it on principles of tenets, retribution and such as that. On the other hand I think it probably has to be the way to do it from what you describe. I think some way to find a notion that would get at the perpetrator must be a much more important answer than trying to develop defensive operations. There must be some way to think in their terms about what they're doing. And not just means-end though. I don't think it's telling someone not to smoke because it hurts you. I don't think they'll listen to that --especially from us.

JL: You introduced a very important ingredient. Find the right intermediaries for that message is the KEY to its success.

AR: Yes. I suppose part of it would be showing them that they would be destroyed but obviously we're dealing with cultures in which self destruction doesn't always really matter -- in terms of suicides...

JL: Do you believe that? Do you think Osama Bin Laden is self destructed. It's one to say -- martyrdom -- whily you pursue your own political objectives.

AR: What do you say about these tapes that show up about him? I often wonder what does that mean? What's he trying to do? Obviously he let's them be shown. They get out. Why would he do that?

JL: Osama?

AR: Yes.

JL: Osama has been looking for leadership in the Muslim world. Every expert in the Mideast and the Arab world that I know stresses this very strongly.

AR: Yes.

JL: We are only incidental to his struggle for supremacy in Islam. But is a pretty clear cut political objective from his general point of thinking. It's reasonably rational behavior. He may miscalculate about his ability to succeed but every regime I know overestimates their capability. There never would be any wars if at least one side didn't miscalculate.

AR: So, you are suggesting that we would have to understand his psychology in order to be able to reverse this.

JL: Of course.

AR: He, personally rather than the culture that he is from.

JL: All of the above. Since he plays in his small circle such an important M_____ role that they're doing their best to exploit that culture for their own dominance. They can _____ in all kinds of fulfillment of the prophet's objectives as well. But there is all boils down to the same thing -- how they can get power.

You know that Arafat said 'I'm perfectly willing to die here'. You remember. He didn't say 'I'm perfectly willing to step down'.

AR: Yes indeed. It's quite important because dying maintains his power. In fact, it might be a desirable thing...

JL: I don't take it at face value.

AR: You don't think the martyrdom would be motivation for people of that sort?

JL: Not at that level of political structures. I think they are far too cynical for that.

AR: To come back to your original point then, it's seems to me that the analogous question is --talking about he psychology of the power person -- why didn't Hilter ever develop the atomic bomb. That would be the analogous question to what you are asking. Was there a factor.... was he afraid it would revolve to him because...

JL: I think I have a very good answer to that in another sphere. It gets complicated and that's why there wasn't a need to use chemical weapons. And yes, he was afraid. He had been gassed himself in WW I and he issued an edict that Germany was not going to expend resources on chemical and biological warfare, largely out of the concern about retaliation. That Germany would not win if they pursued that policy. But he was scared about it. Atomic energy is another story. Germany did not have the industrial capacity to prosecute the war in every other way and then add on the development of atomic energy. And it would have been a fizzle.

AR: Is that so?

JL: Yes.

AR: It really would have.

JL: Yes. From what we know about the ineptitude that Eisenberg brought to it, he tried to make it out that he purposely fudged it but the weight of the evidence is that he just could not work out. But even if he had, Germany could not have pulled it off -- Germany could

not have mounted a Manhattan Project. Now if they had ten years, that might be a different story.

AR: It may be that your point is crucial.

JL: Now the other point to be taken. If you're a totally rational actor he would have surrendered much sooner -- as soon as it was clear his doom was present.

AR: So he was self destructive.

JL: Yes.

AR: In that respect.

JL: Yes. It was a very close call about the rest of his regime might have taken out from under him and that July 20, 1944 -- the attempted assassination was a very close call. The fact that there COULD BE such an attempt tells you something about how much ferment was going on.

AR: But then, other people tried to take over. He was destroying their country. Gehring.... Even some people then...

JL: Oh, the very last days. But they knew all was lost as far as he was concerned. He wasn't being that destructive. He didn't have happy choices.

AR: But something occurs to me in what you are saying Josh. Your point may very well be taken that Osama Bin Laden doesn't understand the biology of it.

JL: That's the point I'm trying to get to.

AR: It may very well be.

JL: Yes.

AR: I was in South Africa for a year and became familiar with a situation there . The amazing thing that happened with _____ because he wouldn't accept the idea of Aids and it's a very strang....

JL: But that's a _____ parallel to it.

[combined talking]

JL: Thank you for reminding me of it.

AR: Now he's accepting it. There were political issues...

JL: There's a very similar kind of education that we are looking for.

AR: It really is.

[laughter]

AR: He got deluded.....it wasn't that he wasn't intelligent enough to understand. He got to take over..... what's his name in California....his theory about.....

JL: Duzzenberg (sp?)

AR: Right. So it may be an issue of educating him.

JL: Thank you for that analogy. It's very important.

AR: There is a precedent for it. There's every reason to believe that they don't know about things like that.

JL: Anyhow I brought it up because you asked me where theory comes into it. Bioterrorism. Not much but HERE's one place... plenty.

AR: It's also theory and politics. There's a lot of important theories. There are some great politicians who are very creative.

JL: Well, how they deal with their constituencies is what they're most notable for.

[laughter]

AR: I always thought that Gorbachev was a great politican.

JL: Certainly. And the way Kennedy handles the Cuban missile crisis.

AR: Right.

Have to go.

JL: Yes, I think so.

AR: Too bad.